The medievalist needs no convincing that William of Ockham (ca. 1285–1347) is worthy of study. At one time Ockham’s views might have been regarded as a clever but uninstructed sign of the decay of Scholastic discourse, but, with the work of such scholars as Philotheus Boehner, Ernest Moody, and Marilyn McCord Adams, those days are now receding into the past. Nonetheless, outside the small circle of students of medieval philosophy and logic, a translation of Ockham’s work on the theory of demonstration, even combined with a broader study of its Scholastic background, may seem to require some justification.

This is unfortunate, for contemporary philosophers should find Ockham a fascinating figure. He is the founder of European empiricism. Like Locke and Hume, he relied on the logical analysis of language to ground a rejection of Platonic metaphysics, and he found the source of all our concepts and knowledge of the natural world in our experience of particulars. Moreover, he avoided that error of Early Modern empiricism that now seems most objectionable: the attempt to construct our public world from purely subjective experience. Ockham is a direct realist, relying on the causal relation between concept and object to establish the concept’s reference. In his view, what makes belief cognition is the right causal relation between the knower and what is known, not the possession of a sufficient justification for one’s belief. Indeed, the accusation of skepticism brought against him, and the skeptical bent of some of his later followers, arises from a typical justificationist misapprehension of his response to skepticism, for Ockham manages without the implausible claim that we can ever have a subjective guarantee that any of our beliefs about the natural world is infallible.

Ockham’s theory of scientific demonstration, the subject of the texts translated and discussed here, presents his conclusions in philosophy of science. In their discussion of demonstration, Ockham and his predecessors approached some of the most fundamental problems of a scientific empiricism, both ancient and modern. How are concepts of natural things formed on the basis of sensory experience? What is the relationship between the notions of everyday people, from which a scientist necessarily begins his research, and the more sophisticated scientific conceptions of these things—can we and the scientist even be said to be speaking of the same things? How are causal principles rooted in the real natures of things?
of things, and how is it possible to know them? How does functionality occur in the natural world? What is the nature and function of scientific knowledge, and how is it related to knowledge of a more ordinary sort? All these questions are dealt with from the standpoint of a scientific realism rooted in the conviction that scientific explanation captures the causal structure of reality.2

But the texts translated here are not only philosophical documents. They depend on, and purport to interpret, Aristotle’s *Posterior Analytics*, and they should be of considerable interest to the modern interpreter of Aristotle. Ockham focuses on a problem that has recently come to the fore in the literature on the *Posterior Analytics*—how does one demonstrate an attribute of a subject?

An attribute (*pathos* or *pathema*) in Aristotle is a characteristic of a subject that belongs to it necessarily and is demonstrable of it, but is not part of its essence. Thus it is not a logical truth that it belongs to its subject, even though it necessarily does so. How can this be? Several scholars have recently approached this problem assuming, as did Thomas Aquinas, that the middle term through which an attribute is demonstrated must be the real definition of the subject. Some have not recognized the possibility of any other solution, though one might in fact take the middle term of demonstration to be the definition of the attribute instead of the subject.1 So Michael Ferejohn provides an account very close to Thomas Aquinas’s view of demonstration, which we discuss below, identifying as first principles certain propositions that are “per se in the fourth way,” that is, true per se due to an efficient causal connection between subject and predicate.4 Hence, developing Aristotle’s example in *Posterior Analytics* II 16–17, he would propose the following as a demonstration that broad-leafed plants shed their leaves: (i) Broad-leafed plants are plants such that their sap solidifies at the juncture of the seed, (ii) any plant such that the sap solidifies at the juncture of the seed will shed its leaves, therefore (iii) broad-leafed plants shed their leaves. Here (ii) is a first principle per se in the fourth way, and the causal connection that makes it necessary is apparent only because the real definition of the subject of the conclusion occurs as its subject. To discover the causal connection between being a broad-leafed plant and shedding leaves, one must discover what broad-leafed plants really are, and then the connection will become evident.5

Richard McKirahan despairs of the attribute’s inherence in its subject becoming evident from the subject’s essence alone, and so he holds that the demonstration of an attribute depends on a “fat definition” of its subject, which includes in it not only a specification of its essence but also all the attributes necessarily belonging to the subject.6 Thus, in the example, the fat definition of broad-leafed plant would be “plant such that its leaves are flat, its sap solidifies at the juncture of the seed, on account of which its leaves fall, etc.”
Owen Goldin, likewise skeptical of Ferejohn’s and Thomas’s approaches, gives up entirely on the use of an essentialist definition of the subject in a demonstration, holding that Aristotle in fact uses a “reductive” definition of the attribute as the middle term of demonstration. Such definitions are discovered empirically. We begin from a “nominal” definition of an attribute, which enables us to identify it, and then work out somehow the real complex of events with which the attribute is identical and which explains its presence in its subject. Hence, in the example, we need to see that the shedding of leaves is, in terms of its nominal definition, a matter of the leaves falling or moving toward the center of the earth. Then we can see that this is in fact a matter of the congealing sap removing any impediment to the natural motion of the leaves, which is downward due to the fact that they are composed of earth and water, as they must be to fulfill their function in the plant. Hence an understanding of what the falling of the leaves of deciduous plants really is, which Aristotle calls a definition of the falling of leaves, is what is expressed in the demonstration that broad-leaved plants shed their leaves. Similar views are found in Albert the Great and Giles of Rome, whose approach we discuss in some detail below.

Ockham must deal with the rich variety of views found in his tradition, and so is far more alive to difficulties in making the definition of the subject the middle term of a demonstration than some of our modern interpreters seem to be. In the end he does settle on this reading of Aristotle, but his consideration of the difficulties leads him to conclude that the highest sort of demonstration, arising as it does from the definition of the subject expressing its essence, can be produced only in mathematics. The reason for this is that the connection between the attribute and its subject outside mathematics, in the natural sciences, is always causal, and causal connections are not knowable through the examination of concepts or real natures alone, but only through experience of relevant causal activity. This view, of course, lies at the core of empiricism, and Ockham may reasonably be regarded as the founder of empiricism in the European tradition.

The philosophical interest of Ockham’s work on demonstration is beyond doubt, then, but to understand it we must first review Aristotle’s *Posterior Analytics* and the tradition of commentary on it to which Ockham responds. We will begin with some remarks on Aristotle.

1. Aristotle’s *Posterior Analytics*

With the rest of Aristotle’s efforts in logic, the *Analytics* must be placed early in a chronological list of his works. Aristotle regarded it as a single work, the division into the *Prior Analytics* and *Posterior Analytics* going back, probably, no further
than Hermippus of Alexandria in the late third century B.C.E. It is, however, patched together from shorter pieces, and the pieces composing the Posterior Analytics were probably, in their final form, completed somewhat after those composing the Prior Analytics. Still, neither of the two completed halves of Aristotle’s lecture course can really be said to have been written before the other—rather, they were worked out together in repeated revisions over a number of years.\(^8\)

The pieces patched together into the final version of the Posterior Analytics were not, it seems, all placed there by Aristotle himself. Book I, chapter 12, for instance, gives advice for conducting oneself in a dialectical debate restricted to a single field of knowledge. Since one may not use a principle from outside that field of knowledge in the debate, much of the chapter relates to the way in which principles come to belong to a particular science (their “appropriateness to the science”), a topic taken up elsewhere in the Posterior Analytics. The rationale for the insertion of the chapter is clear, then, but it is also clear that it is only a piece of a more extensive discussion. It may well be Aristotle’s work, of course, a fragment patched into the most suitable place by an editor intent on preserving it, but surely Aristotle would not have left the discussion incomplete had he himself inserted it. In any case, the largest pieces in the patchwork, around which the rest is organized, are the first ten chapters of Book I and the first nine chapters of Book II. Despite the composite character of the work, it is doctrinally at one with itself, though to see this one must recognize that Aristotle takes “demonstration,” and the “knowledge” arising from it in a stricter sense in some places and in looser senses elsewhere.

The first book of the Posterior Analytics concerns itself with the nature of scientific demonstration. Its concern is science, not epistemology in general, so it does not take demonstration to be an argument that produces conviction or lays out the evidence one has for a belief, because one forms one’s beliefs, and forms them reasonably, before ever doing science. Rather, it makes demonstration an argument that, like a mathematical proof, reflects and makes clear the reason why a fact is so and may even produce understanding of a fact already believed beforehand on very good evidence. For Aristotle’s Posterior Analytics and the medieval work stemming from it, what makes one’s belief scientific is a systematic understanding of the causal order lying behind what one believes. It is not one’s evidence for the belief, no matter how much certainty that evidence may provide.

Aristotle thinks a demonstration is a syllogism arising from first principles, so that a proper scientific understanding of a subject can always be expressed in a formal logical structure of syllogisms arising from first principles. Now, Aristotle’s scientific works proceed not by laying out an already finalized formal deductive structure capturing a network of causes but rather by following the path
of investigation and discovery. They begin by raising the difficulties to be dealt with and reviewing the advantages and disadvantages of the chief theories advanced by earlier thinkers. It should come as no surprise, then, that they provide few if any formal demonstrations in the course of their investigations. The theory of demonstration seems ill suited to provide a logic of discovery—that is, a logic leading us to first principles—given that it proceeds from first principles. Aristotle thought, quite reasonably, that one rises to first principles through a consideration of the facts to be demonstrated from them. Is demonstration irrelevant to the practice of science, then? Might Aristotle have given over his early theory of demonstration when he settled into doing real science?

In fact, the logic of demonstration need not be the same as the logic of scientific discovery to tell us something about scientific discovery. These two logics are not the same in mathematics, Aristotle's prime example of a science, and yet, as any mathematician knows, the goal of formal adequacy can shape research even as one proceeds heuristically in a mathematical investigation. (It may also be noted that, as long as her work clearly can be formalized, a mathematician is often satisfied to proceed informally in order to ease the reader's comprehension and avoid unnecessary labor.) To specify that a science has reached its final goal only when it can be put into the form of Aristotelian demonstration is to say something substantive about the nature of scientific aims and by implication something about the procedures of scientific investigation directed to those aims. For instance, if real definitions must serve as the middle terms for demonstrative syllogisms, this implies a realist and essentialist scientific metaphysics, and the search for real definitions must dominate one's research.

Does Aristotle provide us with any advice how to conduct scientific research? He does suggest in the beginning of Posterior Analytics II that real definitions must be sought out, but he is not generally very precise about how we are to discover demonstrations or come to know first principles. He tells us we must depend on an innate capacity for guessing the right middle terms for the syllogism we are seeking. A demonstration can be found only after collecting a great deal of experience, which both suggests how it will go and provides means for testing its accuracy. He certainly does not expect the scientist to be concerned with the production of explicit, strict demonstrations at the beginning of his work. Much preliminary fact gathering, hypothesis testing, and problem framing, a good deal of common sense, and a little bit of luck are all required before one hits on the cause why something is so, a cause one can use as a middle term to construct a demonstration. But although he does not think a science can be discovered using a rule book, Aristotle may still suppose it helps to keep it in mind that we do not completely understand a fact until we can frame its formal demonstration within a science.
Jonathan Barnes has argued that the art of demonstration provides an account of the form into which a science must be put, once it is discovered and thoroughly worked out, in order to be taught or explained to others. What is required is a deductive structure mounting from the reasons why the conclusions are so up to the conclusions themselves. At the base of the structure are first principles, and no reasons why they are so can be advanced at all, at least as long as one stays within the limits of the science under discussion. Barnes is onto something important here, and though he has been brought under fire repeatedly, a word or two of qualification and explanation should serve to disarm objections.

Despite some unfortunate language, Barnes is not suggesting that the *Posterior Analytics* is a teacher’s manual. The student Aristotle has in mind is the ideal student. To teach such a student one does not need educational psychology or cleverness in exposition. In fact, no one but an expert in the field could follow an Aristotelian science laid out demonstratively, just as no one but an expert mathematician can follow a rigorous formalism in mathematics. Most of actual teaching—anticipating errors; guarding against false inferences; comparing the views of the science to less adequate views that might be more attractive; providing examples, parallels, illustrations, and parables; motivating and testing the student—must go on entirely outside formal demonstration. The failure of non-experts to understand a true demonstration is due to some fault in themselves, to the absence of fully functioning rationality. Pedagogy, not the theory of demonstration, attempts to overcome this lack. Pedagogy directed toward scientific knowledge (most pedagogy, perhaps, aims at other forms of knowledge) should be guided by a conception of scientific knowledge that is drawn from philosophy of science but it is not itself a part of philosophy of science. What we want to know in philosophy of science is what is needful to produce scientific knowing—that is, understanding why the thing is so—in the ideal reasoner. Philosophy of science as Aristotle conceives it abstracts from all considerations other than the kind and logical form of the information needed to produce such understanding. What one needs to know in order to understand, not how we are to get someone to know it in a given situation, is the subject of the art of demonstration.

What, then, is the shape of a demonstrative science? A science arranged in demonstrative form begins from first principles. It provides no reason why such principles are so, but they must be understood and accepted before the learner can proceed. Aristotle identifies four kinds of first principle answering to the conditions that must be met if one is to come to know. (1) One must understand the usage of the terms entering into a science. (2) One needs knowledge of certain “axioms” applicable to more than one science. So, for example, the law of the excluded middle is used in every science; the principle that when equals are subtracted from equals, equals result, is used both in arithmetic and geometry. Such
principles justify the deductions within the science but do not enter into them materially as premises. (More than logical axioms might be admitted into this class, and Ockham fills it with interesting principles Aristotle never envisioned.) (3) One needs to know those indemonstrable truths restricted to the subject matter of the science under consideration that enter into its demonstrations as premises, these being the “first principles” of the science in the usual, narrow sense. (4) One must know the real definitions which enter into the science’s demonstrations as the middle term. The first principles of a demonstration will contain a real definition as its subject or predicate, and discovering why a fact is so, and so discovering its definition, will be a matter of hitting on the real definition that connects the subject and the predicate of the fact to be understood. Principles of the first two kinds it should be observed, do not occur as parts of a demonstration, but are presupposed by it. In particular, definitions expressing the understanding of a term’s usage and how to identify things falling under the term do not occur within the demonstrations themselves, but even scientists who know the real definition first begin from, and never really leave behind, such understandings of usage. After all, we rely on such an understanding in establishing a proposed real definition as a good one. The real definition expresses what we have discovered the thing to be, not our understanding of the use of the term for it, which must be in place beforehand if we are to be able to identify and talk about the thing at all.

The question how we can acquire knowledge of the use of a term or knowledge of an axiom is little considered by Aristotle or Ockham, but the other starting points for demonstration are a different matter. Several places in the Posterior Analytics concern themselves with how we arrive at knowledge of first principles entering into demonstrations through experience and with how we discover real definitions. Aristotle’s treatment of these questions provides Ockham with considerable material for reflection.

For these principles to impart knowledge of a conclusion they must enable us to see both that the conclusion is necessarily true and why it is necessarily true. To accomplish this, Aristotle thinks, the principles of a demonstration must be (1) true, (2) indemonstrable, (3) better known and more certain than the conclusion, and (4) such as to provide the reason for the truth of the conclusion. The first and last of these requirements are obvious enough. As for the second, the principles must be indemonstrable if the explanation why the conclusion is true is to be complete. As long as we can explain further, tracing the explanation back behind the principles to prior causes, we do not yet have knowledge of the conclusion in the strictest sense. When Aristotle is most careful, he relaxes this requirement, specifying only that the premises of a demonstration must either be indemonstrable or else be demonstrated through a chain of demonstrations that eventually devolves upon indemonstrable premises.
The third requirement poses greater difficulties. The principles in a demonstration must be better known than its conclusion if we are not to beg the question. This means that one must be more certain about the principles than the conclusion. The principles of a demonstration are, of course, more universal and theoretical, while the conclusions are more particular and observable, and given that knowledge begins with the senses, one does not begin by knowing the principles better or being more certain of them. But Aristotle thinks that one must, over time, come to believe demonstrative principles with greater certainty than their conclusions if one is to come to know a science. As long as what makes the explanatory principles or causal laws certain for us is our prior certainty about some facts that they explain and that we have observed to be so, the facts are better known to us than the causal laws that explain them. It is like knowing what happened the other evening because only these events could explain our friend’s behavior, rather than determining what happened through independent evidence and only then turning to the explanation of our friend’s behavior. We are not exactly guessing at what the explanatory principles are if we deduce what they must be from our sensory observations, but we have not become directly acquainted with their truth, either.16

So Aristotle does not see scientific demonstration only as a reflection of the logical structure of explanation. Demonstrative science also reflects the order of a certain type of knowledge—that involved in scientific understanding—and Aristotle takes it that if we are to know why they are so, our certainty concerning the facts explained must be rooted in our certainty concerning the explanatory principles. It is the universal causal law that necessitates the effect, and not the other way around, and the order of perfected scientific knowledge must reflect the order of nature.17 So first principles must be better known to us if we are to have scientific understanding, not only “better known without qualification,” that is, prior in the order of nature.18 To be better known without qualification is to be suited to establish the highest form of knowledge—scientific understanding—in an ideal knower. Basing our certainty on what we collect from the senses reverses the order found in nature, for the causes of our knowledge are the effects of what they lead us to know. Knowledge in the strict sense—knowledge why it is so—follows the order found in nature, and in it the explanatory principle is better known and more certain than its observable consequences. An empiricist may question if it is possible to know explanatory principles better than the observations from which they are derived, and that Aristotle thinks it is possible suggests that he falls short of being a full-blown empiricist. Probably we should say Aristotle thinks observations lead us to a knowledge of principles by suggesting them to us, much as a teacher might. Those who have acquired such knowl-
edge do not believe principles on the basis of observational evidence, any more than they believe them on the basis of the teacher’s authority. The principles are self-evident.¹⁹

The premises and conclusion of a demonstration must also be necessary, and they must be per se.²⁰ These requirements, as Aristotle, with Ockham and other medieval commentators, interpreted them, will be discussed in some detail below. For now we should note that a statement can be per se in two ways: (1) “in the first way” if its subject term somehow includes its predicate within its definition, so that “a human being is rational” is per se, and (2) “in the second way” if its predicate term includes its subject implicitly in its definition, as the proper subject for that sort of accident, so that “a human being is able to laugh” is per se. The ability to laugh, though it is not part of the human essence, still occurs only in human beings, that is, in rational, corporeal beings, and that fact is due to the nature of a human being as well as the nature of laughter.

Every demonstration is a syllogism with necessary, per se premises in which the middle term expresses the cause why the predicate of the conclusion belongs to its subject.²¹ Some demonstrable predicates will belong to their subjects convertible and of necessity, so that they are predicates of the species as such. Thus, we can demonstrate that human beings are able to laugh because they are rational (and so can see the point of a joke) and corporeal (and so can reveal this through a corporeal reaction). Necessarily, what is rational and corporeal can laugh, and, since the predicate is convertible with its subject, it is also the case that whatever can laugh is also rational and corporeal. But we can also demonstrate of a species whatever predicates belong to its genera convertible and of necessity, so that one will be able to prove of human beings, for instance, that they have sensory powers since animal is a genus of human being and it is proper to animals to have such powers. In the Middle Ages, the ideal demonstration was called demonstration in the strictest sense, without qualification (simpliciter), or most often, “the highest sort of demonstration” (demonstratio potissima).²² On the account accepted by Thomas Aquinas and many after him, such a demonstration will proceed from premises of which one identifies an essential characteristic of the subject (and so is per se in the first way), while the other identifies some property that is not found among the essential characteristics in question but still necessarily belongs to whatever has those characteristics. So it is demonstrated that the predicate of the conclusion is a necessary proper accident—in the usual medieval terminology, a property (proprium) or attribute (passio, from Aristotle’s pathema or pathos)—of its subject. On another account, accepted by Albert the Great, the relevant essential characteristics of the subject will be presupposed in some manner in a demonstration but will not occur as the middle term. Rather,
the definition of the attribute will. On Thomas’s account, then, some attribute will be immediate in the definition of the subject, without a middle term by which it can be demonstrated, and the proposition asserting such an attribute of its subject’s definition will be a first principle. On Albert’s account, some attribute’s definition will be immediately in the subject itself, again yielding an indemonstrable first principle.

A science constructed on Thomas’s model will reveal the essential structure of its subject and show us what properties necessarily follow on each aspect of its essence. Since the number of genera under which a species may fall is strictly finite, and since each genus will be associated with a single proper accident that it causes in the subject (or at least a finite number of such accidents), such a science will have a finite number of principles and conclusions. The assumption of the medieval commentaries is that a science must take a substance as its subject matter, but it is not easy to pin that opinion on Aristotle. Probably he did think of the science of a substance as the highest sort of science. A science built up on the essence of a color, for instance, though it might have the same structure as the science of animals, would leave something unexplained, inasmuch as color is parasitic on the surfaces in which it inheres. But animals stand alone, depending on nothing in which they necessarily inhere for their being. Deep and interesting issues are raised by all this, and we shall examine them in some detail as we review the opinions of Grosseteste, Albert the Great, and Thomas Aquinas on the nature of the ideal sort of demonstration.

Aside from ideal demonstration in the strictest sense, demonstration why a thing is so (demonstratio propter quid), Aristotle considers in the Posterior Analytics demonstration that a thing is so (demonstratio quia), which does not adequately explain its causes. Such demonstration does not enter into a perfect science, but he does not take an interest in only the most perfect knowledge. He is also concerned with knowledge of the inferior sort that may involve certainty but no clear view why the fact known is the case— he wishes to contrast scientific knowledge with this inferior sort and work out how the two are related to one another. To this less perfect knowledge corresponds a less perfect sort of demonstration. Demonstration that it is so is of several different kinds:

1. We may have a demonstration that occurs later in the structure of a science, arising not from first principles but rather from conclusions of earlier demonstrations. If we are in fact unable to demonstrate the principles of our demonstration starting from indemonstrable principles (that is, if we do not possess the entire science), it will be a mere demonstration that it is so, not a demonstration why. Such a demonstration may be part of a science in devel-
opment, which has not yet been carried back to its first principles. It will become a demonstration why only when the science becomes complete enough to carry it back to its first principles.\textsuperscript{25}

2. We may argue from effect to cause instead of cause to effect. In this case the demonstration that it is so will be no part of any science at all but will lead to knowledge in a loose sense, namely, that sense in which we have knowledge as long as we have good enough evidence and get it right. For example, we might argue that the stars are far away because the stars twinkle, and whatever is far away twinkles. Such a demonstration can be converted into a demonstration why (of a different conclusion) by switching the conclusion and the minor premise, so that we get, “the stars are far away, whatever is far away twinkles; therefore the stars twinkle.” When a medieval author refers to demonstration that it is so, it is usually this sort of demonstration he has in mind.

3. We may have a demonstration with principles lying outside its science, for instance, a demonstration in optics, which might rely on principles or demonstrable conclusions drawn from geometry.\textsuperscript{26} In such a case a knower in the strict sense must know the higher science as well as the lower, but a knower in a looser sense may borrow the necessary information from the higher science, accepting its authority without possessing knowledge of it.

4. Finally, there may be a demonstration in a loose sense if the conclusion and premises are only for the most part true, and not necessary,\textsuperscript{27} or again, the demonstration concerns a particular such as the moon and an attribute that is only sometimes true of it.\textsuperscript{28} This last sort of example provided much material for reflection to Ockham and other medieval authors. Aristotle’s text can be quite confusing if we do not keep in mind that he often speaks of demonstration, not in the ideal sense that seems involved in the opening sections of Books I and II, but in various loose senses connected with loose senses of knowledge not involving a complete grasp of causes. Of course, such demonstrations will not meet all the requirements laid on the ideal sort of demonstration. It should be noted that many conclusions will be incapable of the highest sort of demonstration. The only demonstration available for conclusions that are not true always and necessarily—and hence for any conclusion concerning a particular, for instance, that the moon is eclipsed—will be a demonstration that it is the case. Aristotle inherits Plato’s conviction that only the eternal and unchanging is a possible object of knowledge in the highest sense. Again, it may be that there can be no understanding of optics without bringing geometry into it, and so it may be that only demonstration that it is so can occur in this science.
2. The First Generation of Medieval Commentary: Robert Grosseteste

2.1 The Introduction of the *Posterior Analytics* to Medieval Europe

The Latin West knew the *Posterior Analytics* only by reputation between the disintegration of the Western Roman Empire and the twelfth century. It then recovered this book, with much else of Aristotle, through Latin translations both of the works themselves and of Arabic paraphrases and commentaries on them. From the beginning of the twelfth to the end of the thirteenth century, at least four medieval translations of the *Posterior Analytics* into Latin were made. In this period Latin translations were also made of two Greek commentaries written in late antiquity, that of Themistius (ca. 320–ca. 390 c.e.) and one attributed to Alexander of Aphrodisias (fl. ca. 200 c.e.) that seems in fact to be a version of the commentary of Philoponus (ca. 490–570 c.e.). Also translated were Arabic commentaries by al-Farabi (873–958) and Averroës (1126–1198), and several other works from which some knowledge of Aristotle’s theory of demonstration could have been gleaned.

Boëthius (ca. 480–524 c.e.), the last student of logic in the Roman West, was a patrician who rose to the highest level in the civil service under Theodoric, the Visigothic king of Italy. He attempted to preserve as much as he could of the work of Aristotle for the West by writing Latin translations and commentaries, since learning Greek had become the rarest of accomplishments in the West in his time. He managed in fact only to translate a portion of Aristotle’s logical works since he suffered an early death, executed under suspicion of treasonous communications with the eastern emperor, but his translations and commentaries formed the foundation for the study of logic and philosophy in the Latin West through the twelfth century. Boëthius reports a translation of Themistius’s paraphrase of the *Posterior Analytics* by Vettius Agonius Praetextatus, which would have been the earliest rendering into Latin. Boëthius himself may also have translated the *Analytics*, but if so, neither his translation nor that of Praetextatus survived into the Middle Ages. The early Middle Ages possessed only the so-called “Old Logic,” that is, Aristotle’s *On Interpretation* and *Categories*, with the *Introduction* (Isagoge) to the *Categories* by Porphyry and commentaries of Boëthius and others. The earliest Latin translation of *Posterior Analytics* we possess waited upon the flurry of translation in the twelfth century, which led to the recovery of Aristotle’s work for the West and in particular to the recovery of the “New Logic,” that is, the *Prior Analytics*, the *Posterior Analytics*, and the *Topics*. James of Venice made a translation of the work directly from the Greek, perhaps between 1125 and 1150. This *Posterior Analytics* is mentioned in John of Salisbury’s *Meta-
logicon (1159), which contains considerable information about demonstration, and is also praised by Alexander Neckam (1157–1217) in his discussion of demonstration in De naturis rerum. From about 1250 on, the James translation was the vulgate, and the revision of it done by William of Moerbeke (ca. 1269) from a good Greek text seems to have been used by no one but Thomas Aquinas. The other translations, also with low usage, were done from the Greek by one Johannes, who is mentioned in John of Salisbury and probably worked between 1125 and 1160, and from an Arabic text by Gerard of Cremona (d. 1187).

Gerard also translated the paraphrase of the Posterior Analytics by Themistius, which was used most especially by Albert the Great (1206–1280). Albert used a translation of al-Farabi’s more extensive literal commentary as well, or at least some author who quoted it freely. Both translations dropped out of circulation quickly, and later citations of these authors generally depend on Albert. A translation by James of Venice of the commentary attributed to Alexander of Aphrodisias survived only in marginal glosses. Averroës’s Middle Commentary was translated by William of Luna around 1300, but seems never to have been used before the later fifteenth century, unless it was used by Albert the Great, who seems to have adopted some of Averroës’s central views but does not cite their author by name. It appeared in two printed editions: at Venice in 1483 and Lyon in 1530. The situation, then, with reference to ancient commentators was not particularly good in the fourteenth century when Ockham wrote. It is noteworthy that Averroës was not known, and other Arabic authors were known generally only through the reports of Albert the Great in his commentary on the Posterior Analytics (written probably between 1245 and 1260), though it is to be noted that many of the ideas in these authors had established themselves in the tradition, even if the authors themselves were no longer consulted. This situation seems to have arisen due to a rapid loss of interest in Greek and Arabic work as the Latins established their own understanding of the Aristotelian text, for the material that was possessed at one time, reflected in Albert’s commentary, was allowed to drop out of circulation, and the translation of Averroës was apparently simply ignored.

2.2 The Commentary of Robert Grosseteste on the Posterior Analytics

Despite the materials available in the twelfth century, the theory of demonstration was at first little noted and found no use outside a few logic manuals such as John of Salisbury’s Metalogicon. It did not enter into the mainstream of European thought until Robert Grosseteste (ca. 1175–1253) produced the first full-scale Latin commentary on the Posterior Analytics in about 1230. His commentary was immensely popular and became the standard work in the first half of
the fourteenth century. It continued in use even into the sixteenth century and appeared in at least eight printed editions between 1494 and 1552. Grosseteste was a major author for Ockham.

Like Ockham, Robert Grosseteste was associated with the Franciscan order. He studied at Oxford, and perhaps Paris, from 1209 to 1214. He was elected bishop of Lincoln in 1235. Grosseteste was quite prominent as a scholar of the new Aristotelian science, but he made himself a spokesperson for a conservative, Augustinian-Platonist viewpoint in philosophy, which he read into Aristotle. For this reason, as we shall see, his reading of Aristotle was attacked by the more radical Aristotelians of the Dominican order who emerged later in the century, in particular, by Albert the Great and Thomas Aquinas.

Grosseteste's commentary proceeds through the text passage by passage, often taking on the character of a literal commentary when the going gets tough, descending to a discussion even of grammatical points. In most places, though, it settles for a paraphrase of the passage discussed, first giving a brief account with indications of the relation of the passage to the larger context, and then a more detailed discussion if the text is difficult or interesting. Grosseteste often goes beyond the text, especially to introduce the doctrine of divine illumination or to discuss mathematical and scientific points, and he often elaborates on it in a manner calculated to square Aristotle with his own Augustinian background. He stays away from formal *quaestiones* and very rarely mentions the views of other commentators, Arabic or ancient, that he might have been expected to know. The whole book is relatively short and generally concise in its treatment.

Grosseteste identifies the purpose of the *Posterior Analytics* as the development of a demonstrative science of demonstration, using the account of demonstrative science he finds in the book in its own analysis. He expects the properties of demonstration to be demonstrated of it, using the definition of demonstration as the starting point and middle term of his demonstrations. (Some ramifications of this expectation for Ockham will be discussed below in section 5.5.) On Grosseteste’s analysis, thirty-two such demonstrations are found in each of the two books of the *Posterior Analytics*, and their conclusions, identified as they appear in the text, form the framework of the commentary’s discussion. Early on he does a fair job of formalizing the science, identifying the necessary definitions and laying out the demonstrations carefully with their underlying assumptions. Things degenerate, though, in the latter part of Book I and in Book II, so that the list of conclusions becomes a mere summary of the chief points, with little of the deductive structure behind it worked out. Necessarily many parts of the text must be placed outside the formal presentation of the demonstrative science. So in Book I, chapters 3, 5, and 15–22 contain no demonstrations belonging to the science, but they are, Grosseteste says, concerned with disproving com-
mon errors concerning demonstration. Generally his explanations of these sections of the text are plausible.

According to Grosseteste’s account, the conclusions for Book I all concern demonstration directly, but fall into four groups: (1) seventeen conclusions in chapters 1–13 concern demonstration as such; (2) one in chapter 14 concerns demonstration considered as syllogism; (3) nine in chapters 15–27 concern the relations of demonstrations to one another considered as such, for instance, which sort of demonstration is better or more certain; and (4) five in chapters 27–34 concern demonstrations as they are grouped into sciences. Book I, Grosseteste remarks, tells us everything we might wish to know about demonstrations in order to be able to distinguish them reliably from those pretenders that are not really demonstrations, but it does not tell us how to discover them. For this we need the art of definition, since the discovery of a demonstration is tantamount to the discovery of the middle term, which is a definition. Hence Book II deals with the art of defining, and perhaps it is because this is a practical art that the deductive structure evident in the discussion of the first book is so much less evident in the second. In Book II, (1) five conclusions concern what sorts of things can be asked and known (chapters 1–2); (2) ten conclusions are about definition as it is related to demonstration (chapters 3–10); (3) six conclusions concern the middle of demonstration considered as a cause (chapters 11–12); (4) ten conclusions concern the art of defining (chapters 13–14); (5) one conclusion is about causes, specifying there is but one cause and one middle term for one conclusion demonstrated per se (chapters 16–18); and (6) an epilogue to the whole work concerns the acquisition of principles, though this subject is strictly incidental to the science of demonstration (chapter 19).34

Why did Grosseteste’s commentary succeed in introducing the theory of demonstration into the mainstream of European thought, when no earlier discussion did so? Some remarks in John of Salisbury’s *Metalogicon* indicate that before Grosseteste the text of the *Posterior Analytics* was regarded as a very difficult one, both in its doctrine and its language. Moreover, the text may also have been viewed with suspicion because of its disagreement with the dominant Augustinian epistemology of the period.35 If the latter was indeed a difficulty, Grosseteste’s commentary might have seemed to baptize the heathen text as well as explaining it. Its interpretation of Aristotle’s doctrine rendered it consistent with Augustine’s Neoplatonic views at every point by treating demonstrative science as the manner of knowing the natural world necessary to fallen humanity. It reserves more Neoplatonic sorts of knowledge for our restored or supernaturally assisted nature in the contemplation of God and of the natural world in God. Indeed, McEvoy says that Grosseteste “made evident his view that Aristotle’s philosophy represents one level of truth and no more than that, and his commentary
became something like a celebration of the superiority of revealed Christian truth over the sapientia mundi.” No doubt, the fact that Grosseteste became a prominent and philosophically conservative bishop, with no taint of the radical Aristotelianism emerging later in the thirteenth century, would have helped obviate any difficulties in using his commentary or Aristotle’s text.

We shall find that a medieval interpretation of Aristotle’s Posterior Analytics can only be properly understood once we have grasped the epistemological and metaphysical presuppositions of the interpreter. Aristotle’s text was treated rather like sacred scripture, which might receive very different readings from different metaphysical and theological orientations. Grosseteste, Thomas Aquinas, Albert the Great, and William Ockham each approached the book from the standpoint of his own metaphysics, and since the book’s concerns center on formal matters (the form of a scientific theory), its doctrine could be explained rather differently, without obviously abandoning what it says, from very different viewpoints. Indeed, since the structure of an Aristotelian science reflects the causal structure of the world, a philosopher’s metaphysical views concerning that causal structure shape decisively his view of both the general structure of an Aristotelian science and the relations of various sciences to one another. Hence Grosseteste’s Augustinian Neoplatonism, the different varieties of Radical Aristotelianism found in Albert and Thomas, and the Nominalism of William Ockham might all seem, each to its own adherent, to provide the key to understanding the Aristotelian text. To get a proper understanding of Grosseteste’s commentary on the Posterior Analytics, then, we must first consider his Neoplatonic view of the causal structure of the world.

2.3 Grosseteste’s Augustinian Illuminationism

The Augustinian theory of knowledge current when Grosseteste wrote held that the forms of things are ideas found in the divine mind. Human knowledge of eternal and necessary truths is rooted in access to these exemplary forms. Thus, since it is always higher things that act upon lower things, not lower that act upon higher, it is only illumination of the human mind by God, accomplished through the active influence of the forms in God’s mind on the human intellect, that can produce the intellectual vision of the form necessary for this knowledge. The activity of these forms is likened to the activity of light on the eye: they are intelligible of themselves, as light is visible of itself, and they make other things intelligible as light makes other things visible.

One thing to be explained here is how knowledge of nature or mathematics could involve a vision of ideas in the divine mind without a direct vision of the divine mind itself, for that would be a beatific vision reserved to the blessed.
Grosseteste thinks if the mind were healthy—that is, if it were not subject to the effects of Adam’s fall—it would indeed have the power to see God in Himself without any mediation and in Him all the things he had created. But as things are, there is in this life no vision of God or of the exemplary forms in God. Rather, the divine light—which is the Truth itself—provides a thing with its form and then illuminates the form so the intellect can see it.

Grosseteste thinks we can know the form of a natural object in the divine light, without knowing the exemplary form in the divine mind directly, only because these two forms are the same. But if they are the same, why don’t we see the exemplary form in our vision of the natural form belonging to a created particular? Because the natural form is the exemplary form only as it occurs in the natural world. The form of Bugs is the exemplary form of rabbit expressing itself in the natural world in this particular matter. The exemplary form is conceived by Grosseteste to cause the form of Bugs to inhere in Bugs’s matter through a perfect reproduction of itself—or perhaps we could better say that it itself enters the matter of Bugs (as well as the matter of Bugs’s girlfriend, Boadicea), and it is only said to reproduce itself, as though a second form were introduced by the process, because it becomes distinguishable from other manifestations of itself in other chunks of matter when it enters Bugs’s matter. This new way of being the same or different—being the same or a different particular—has no application at all to the exemplary form considered in itself, and indeed in every way in which the exemplary form can be the same as something, it is the same as both Bugs and Boadicea. But in this new way, Bugs and Boadicea are different from one another, even though both are, of course, the same as the exemplary form of rabbit in every way in which something can be the same as the exemplary form of rabbit.

Grosseteste argues, then, that the universal is neither one nor many (particulars) considered in itself, and he suggests that

the unity of the universal in many particulars is similar to the unity of light in light that produces and light that is produced. Light that is in the sun produces light in the air from its substance, nor is anything new created as it is light in the air, but the light of the sun is multiplied and propagated. Thus, light in the sun and in the air are other than one another, but not entirely other, but in a way there is a unity of essence in the producing and produced light, for otherwise the light produced would be created wholly from scratch and out of nothing. Therefore a universal is not only a creation of the mind, but is some one thing in many.

Although the generated and generating light are different particular instances of light, still they must have a unity of essence or else the generated light would be
created out of nothing rather than arising naturally through the multiplication of forms. We shall find it most important that this unity of essence is so intimately connected with a causal relation. The upshot, then, is that we see the natural form only in the light of the exemplary form, for it is only because the natural form is the exemplary form that it is intelligible, but we do not thereby see the exemplary form in its own person, as it were, but only as it occurs in natural particulars. With our minds clouded by sin, we come to knowledge of a form only through sensory perception of natural particulars that have it, and so we do not see God’s mind.

Now the contribution of the divine light in natural knowledge is not only to make the created form intelligible through its identity with the exemplary form—it also causes the form of the created thing to be seen actually by the intellect. In his _Hexaëmeron_ Grosseteste tells us that color is light that has been incorporated. Like all light, it wants to propagate itself to form a sphere, but its incorporation prevents this. Only if unincorporated light illuminates it from without is it activated and made capable of expanding outward and affecting the eye. Similarly, the divine light is not itself seen, but only activates and so reveals the incorporated forms of things embedded in matter and its accidents, as well as in our sensory experience of these things, and those forms can only be understood by us because of its presence. (Neither Aristotle nor Grosseteste held to the view that light is reflected from an object into the eye, and so there is no question of the divine light itself entering the soul and somehow becoming “visible” in this process.)

Few human beings are aware of the operation of the divine light, but this is no proof that it is not present, and necessary, in the intellectual perception of the forms of created things. To become aware of it, human beings must either be blessed, so that they see God in Himself, or wise, so that they understand the processes of cognition.

2.4 Light and Forms: The Causal Structure of the Created World in Grosseteste

Grosseteste’s account of how we know the forms of natural realities in the divine light leads us to ask how precisely the higher, exemplary forms of things in God’s mind are related to the natural forms as they occur in the world. If we conceive this relation as a purely formal one, a difficulty emerges when we consider material things, for to define what a material thing really is, it seems we need to describe its material parts and their relations to one another, for instance, their arrangement in space. Does the exemplary form of the thing in God’s mind contain within it a specification of these relationships? It is difficult to see how it could, since these relations are due to the presence of the form in matter.
and would not be present with the exemplary form, which is separated from matter. Grosseteste’s answer is that these spatial relations are not in fact present in the exemplary form formally, but are only present, as it were, potentially. If the form in God’s mind is to be realized in the material world, there are only a limited number of ways in which this can happen, and so the spatial relationships of the material parts in its realization can be derived from the form. It is rather like the specification of the form of an artifact in a person’s mind. That form may only specify the purpose and functions of the artifact, without specifying how those functions are to be realized in the material from which the artifact must be made. It may well be the case that there are multiple possible realizations. So the notion of a camera might be in the engineer’s mind, that is, the notion of something that will record images as they appear to our eyes permanently on a flat surface, and there may be many ways to construct such a thing (cameras employing film and digital cameras, for instance). Still, one might suppose that there is not an indefinite number of ways to construct it, and the form of camera in the mind, though it does not contain an account how it is to be realized, if it is taken together with existing technologies and available materials, is sufficient to specify such an account or a finite number of such accounts. Grosseteste imagines, for instance, that there might be a form of knower in God’s mind, which could be realized in various ways in different sorts of matter, though the form in itself is simple and does not contain within itself any specification of the material structures needed to realize it.

It should be noted, though, that Grosseteste, as a Platonic Realist, takes it that the form itself can exist quite independently of its realizations, and indeed that it brings about its own realizations through its natural tendency to reproduce itself in whatever way is possible in the material world. The modern engineer likely is not a Platonic Realist and so will not think of the form in his mind as causing its own realization, but Grosseteste would argue that it does bring about its own realization by bringing about the engineer’s actions. If we imagine an engineer so powerful that his will alone, without any external bodily actions directed by it, could bring about the existence of a thing, then we have some notion how the ideas in God’s mind realize themselves, so that the form is the efficient cause of that which participates in it and preserves that thing in being.43

For details, let us turn to Grosseteste’s De luce, which presents a speculative Neoplatonic cosmogony inspired by Book XII of Augustine’s Confessions. Grosseteste argues that light is the “first form” of matter, which prepares it to receive every other form it is capable of by providing it with geometrically ordered extension. Light is in itself pure form, and so it is simple or incomplex, that is, it lacks any structure of parts and is neither extended nor in any way corporeal or spatial. Its simplicity is reflected in its material realization by its occupation of a
single point without dimensions or parts. But light has the natural tendency to reproduce itself, and this reproduction is necessarily of many instances of the same species, distinguishable only by their different positions in space. For this reason, light’s ability to reproduce itself, realized in the natural world, leads it to spread out in three dimensions. Thus light is extended, instantaneously, into a finite sphere, producing extended matter. Since each instance of light occupies a mere point, an infinite reproduction is necessary to produce the sphere; and only a finite space can be covered by the infinite, point by point reproduction of light, so that a sphere of finite diameter is produced. But matter has weight (it seeks to return to the center from which the light that is its form was first propagated), and so the matter of which light is the form is more rarified further out. Note that, since each point in space is, as it were, occupied by a simple substance in the species of light, the physics of light is perfectly parallel to the construction of Euclidean space. It is for this reason that light is the first form of matter: it provides matter with the underlying geometrical structure of space, even if it does not describe or contain this structure, as it were, within its essence but rather generates it in its reproduction of itself.

Now the outer part of the original sphere of matter is rarefied as far as it possibly can be and is therefore perfectly actualized. Grosseteste thinks that the most fully actualized light will be that which is closest to pure form and so the least material, hence the most rarefied of matter. Being fully actualized light, this outer sphere is intelligent and intelligible, and it retains the power to reproduce itself, that is, to produce light, and since this light cannot be diffused outward, it is reflected inward, back into the center of the sphere. This is possible because the more interior parts of the sphere of matter produced by light’s first expansion are more dense and so capable of expansion, that is, they are not fully actualized light. As a result of this illumination of the incompletely formed matter below it, the first sphere fully actualizes the matter nearest it, for the matter below it is rendered heavier, and as it sinks further into the center, the matter left furthest out, adjacent to the outer sphere, becomes more rarefied. The second sphere then illuminates the space below it, which is illuminated by a threefold light. The process is thus repeated, until the nine heavenly spheres have each been produced. Each sphere actualizes and illuminates the spheres below it, each is made perfect by the spheres above it, and each, being fully actual, is free of unrealized potentiality and so incapable of change. The matter below the sphere of the moon, however, becomes so dense that it cannot be fully actualized by the moon’s light, and so below the moon change is possible, since the matter there can be attenuated, even if it cannot be perfected, by the introduction of more light. Below the moon, then, the spheres of fire, air, water, and earth are produced. Fire receives the form of light to such an extent that it can form the basis of perception and illuminate the mat-
ter below it, producing heat which tends to perfect that lower matter, turning it into fire. Air, in the next sphere below, is no longer luminous, and water and earth, lower yet, are incapable of outward expansion, retaining only weight. The incompletely actual matter below the moon, then, forms composite bodies subject to change and irregular motion arising from the action of celestial powers, in particular, the light of the sun.46

Now we have said that light is the primary form of the matter that arises from it, but it must be noted that a chunk of matter is not exactly a piece of light. A single instance of light, considered as it is in itself, would be at a single point of space. It is not even correct to say that this instance of light is a part of a chunk of matter, for a part of a chunk of matter, as Grosseteste well knew from Aristotle, would have to occupy some interval of space and could not be a mere point. Nonetheless, if the light is removed, the matter is, and everything true of matter is true of it in virtue of the realization of light in space. So the science of matter will depend on the science of light, but the definition of matter will not define it as a genus of light. What is essential to light—its simplicity, for instance—is not essential to matter, and what is essential to matter—its extension—is impossible to light. Nonetheless, light is the primary form of matter, for a chunk of matter is an infinite collection of instances of light, of points related to one another geometrically inasmuch as they form lines and spheres, which is due to generative relations of light to light. Indeed, matter can only be understood in terms of geometry. Grosseteste assures us that “matter arises from light in accord with mathematical laws, so that all causes of natural effects can be discovered by lines, angles, and figures, and in no other way can the reason for their action possibly be known.”47 At bottom the reason for this is that material powers are always powers to propagate forms in straight lines through space in the same way that light propagates itself through space. Optics, for Grosseteste, provides the key to physics.

There are two points to be emphasized here. One is the point just made: matter arising from light, which has light as its primary form, does not belong to the same genus as light. Light and earth do not fall under the same science, but the science of earth can only be understood through the science of light. The other is the point made at the beginning of this section: we might understand the form of a thing fully without understanding how concrete instances of that sort of thing in fact occur under specific circumstances. One can know what a camera is, and this is essential to coming to know cameras as they actually occur in a given technology, but the discovery how they occur in that technology requires us to consider more than our understanding of what a camera is, for we have to consider how such a thing can be realized within that technology. With these two points in mind, let us now turn to Grosseteste’s treatment of the *Posterior Analytics.*